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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2016/2017

ETM3086 – MOBILE AND SATELLITE COMMUNICATIONS (TE)

30 MAY 2017
2:30 P.M. – 4:30 P.M.
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of 8 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

QUESTION 1

(a) For a single base station mobile radio system, given that a user make 2 calls per hour which each call lasts an average of 3 minutes.

(i) What is the traffic intensity for each user? [1 mark]

(ii) Calculate the number of users that could use the system with 2% blocking for 10 and 5 trunked channels. [2 +2 marks]

(iii) If the number of users becomes 20 users, what is the new blocking probability of the 5 trunked channel mobile radio system? [3 marks]

(b) Handoff is one of the important concepts for deployment of cellular system. Explain handoff mechanism with the aid of a diagram. [3 marks]

(c) The increase in demand for wireless service will result in insufficient number of channels assigned to a cell to support the required number of users. To solve the problem, cellular design techniques are required to provide more channels per unit coverage area. Techniques such as cell splitting and sectoring are used in practice to expand the capacity of cellular systems.

(i) With the aid of a diagram, explain how cell splitting and sectoring can be done. [6 marks]

(ii) List **TWO** effects of sectoring. [2 marks]

(iii) Calculate the signal-to-interference ratio (S/I) for a 7-cell repeating pattern, given that path loss exponent, n equal to 3 and 6 first tier co-channel cells are used. Next, if sectoring is applied in such a way the antenna covers 120° , find the S/I improvement. [6 marks]

Continued...

QUESTION 2

(a) Pretend you need to design a radio communication link in your hometown. However, by law, the transmit power has to be kept not more than 40 watts. Assume you use unity gain transmit and receive antennas and the receiver sensitivity is -100 dBm.

- (i) By using the two-ray propagation model, suggest the antenna heights for the transmitter and receiver if the desired radio link is 5 km and 10 km?
- (ii) If the height of the transmit antenna is 100m when the receiver sensitivity is -100 dBm, how much higher must the transmit antenna be raised to obtain an increase from -100 to -90 dBm in the received signal?

[4+2 marks]

(b) Assume there is a cellular base station with a transmit power of 40W.

- (i) Find the transmit power of the base station in units of dBW and dBm.
- (ii) Calculate the received power in dBm at free space distance of 100m if the transmitter power is applied to a 1dB gain antenna with a 1800MHz carrier frequency.
- (iii) Repeat (ii) for a distance of 5km. Conclude your answer.

[2+3+2 marks]

(c) Assume that extensive measurements have been done in an area and a multipath channel model is constructed whose power-delay profile consists of 4 paths arriving $0.1\mu\text{s}$ apart. First path arrives and assumed to have unit power (0dB), and, subsequent paths have 3dB reduction in power as compared to the previous one. What is the largest transmitted signal bandwidth that would go through this channel without experiencing frequency selective fading?

[8 marks]

(d) Explain the near-far effect and describe two remedies that can alleviate it.

[4 marks]

Continued...

QUESTION 3

(a) Given that communication between an earth station and a satellite is restricted to time when the satellite is at an elevation greater than 10 degrees. Determine the minimum and maximum distance between an earth station and a geostationary satellite. Hence, compute the minimum and maximum round-trip propagation delays. [6 marks]

(b) With the aid of diagrams, explain the following orbital aspects of satellite communications:

- (i) Inclination
- (ii) Perigee and Apogee
- (iii) Orbital Nodes

[2+3+4 marks]

(c) The orbit for an earth-orbiting satellite orbit has an eccentricity of 0.2 and a semi-major axis of 10,000 km. Estimate the apogee and perigee altitude and the satellite velocity at apogee and perigee. [6 marks]

(d) For the satellite in (c) above, at a given observation time, during a south to north transit, the height above ground is measured as 2,000 km. The argument of the perigee is 270° . Determine the corresponding true anomaly of the satellite. (Hint: $r = a(1 - e^2) / (1 + e \cos \nu)$; assume a mean value 6371 km for the earth's radius) [4 marks]

Continued...

QUESTION 4

(a) List **FOUR** losses which need to be taken into consideration in designing a good satellite communication system. [4 marks]

(b) A link budget for a transparent satellite uplink is shown in **Table Q4** below.

Table Q4

Path	Parameter	Unit	Value
Uplink Earth Station	HPA output power	dBW	2.00
	Feed loss	dB	1.05
	Antenna gain	dBi	41.0
	Pointing loss	dB	0.20
Uplink path	Uplink frequency	GHz	6.0
	Uplink range	km	38000
	Uplink rain attenuation	dB	2.68
Satellite	Satellite saturated power flux density (SFD)	dBW/m ²	-84.56
	Satellite antenna gain to noise temperature ratio (G/T)	dB/K	-0.15
	Uplink Carrier to cross-polarization interference ratio (C/XPD)	dB	27.31
	Uplink Carrier to adjacent satellite interference ratio (C/Adj)	dB	37.32

If the noise bandwidth is 105 kHz, compute:

- The earth station transmitted EIRP in dBW. [2 marks]
- The uplink (free space) spreading loss in dB. [3 marks]
- The received power flux density by the satellite in dBW/m². [3 marks]
- The satellite input back-off in dB. [2 marks]
- The uplink carrier-to-thermal noise ratio (C/N)_{thermal} in dB. [8 marks]
- The total uplink carrier-to-noise ratio (C/N) in dB. [3 marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	$3.986 \times 10^{14} \text{ m}^3/\text{s}^2$
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	$3 \times 10^8 \text{ m/s}$
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	$1.379 \times 10^{-23} \text{ J/K} = -228.6 \text{ dBW/Hz K}$

Appendix II: Table of Complementary Error Function

$$\text{erfc}(z) = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-t^2} dt \text{ for } 0 \leq z \leq 3.99 \text{ in steps of 0.01}$$

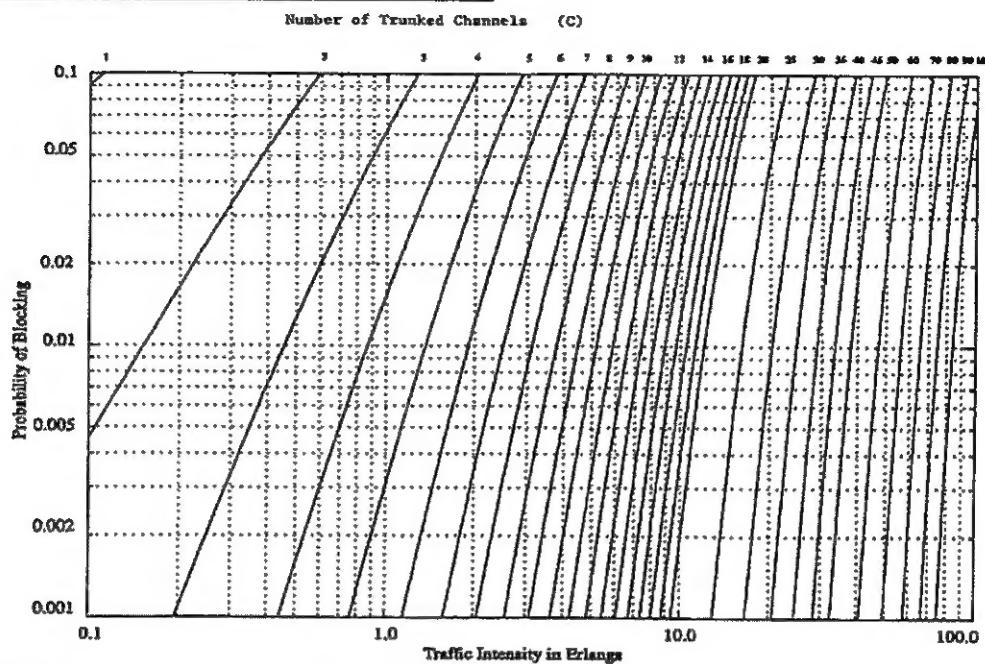
z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.686E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-04	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: $1.000E-01 = 1.000 \times 10^{-1}$

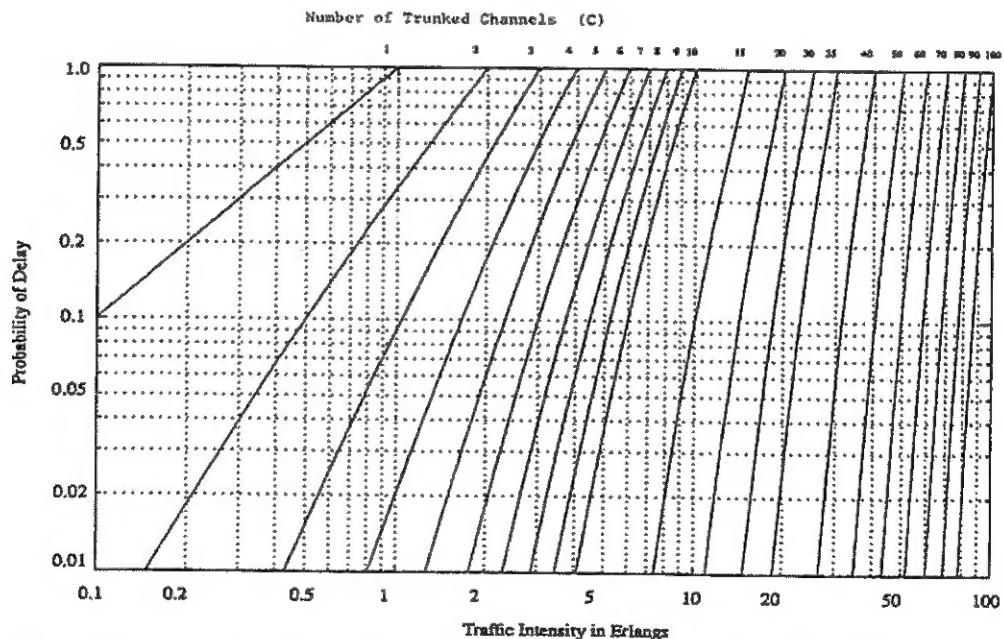
$$\text{For } z > 4, \quad \text{erfc}(z) \approx \frac{1}{\sqrt{\pi}} \left(\frac{e^{-z^2}}{z} \right)$$

Continued...

Appendix III: Erlang B and Erlang C Chart



The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Continued...

Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

$$v_s = \sqrt{\frac{\mu}{a} \left(\frac{2a}{r_o} - 1 \right)} \quad SIR = \frac{P_r}{\sum_{i=1}^K P_i} = \frac{1}{\sum_{i=1}^K \frac{1}{\left(\frac{D_i}{R} \right)^n}} \quad T^2 = \frac{4\pi^2 a^3}{\mu} \quad r = \frac{a(1-e^2)}{1+e \cdot \cos(\theta)}$$

$$b = a\sqrt{1-e^2}$$

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

$$\text{Power flux density, } \phi = \frac{EIRP}{4\pi R^2}$$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D :

$$G_{max} = \left(\frac{4\pi}{\lambda^2} \right) A_{eff} = \eta \left(\frac{\pi D}{\lambda} \right)^2 = \eta \left(\frac{70\pi}{\theta_{3dB}} \right)^2, \text{ where } \theta_{3dB} = 70 \left(\frac{\lambda}{D} \right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

$$\text{Free space loss, } L_{FS} = \left(\frac{4\pi R}{\lambda} \right)^2$$

Noise power spectral density, $N_o = kT$

$$\text{Noise factor, } F = 1 + \frac{T_e}{T_o}$$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{el} + \frac{T_{e1}}{G_1} + \frac{T_{e2}}{G_1 G_2} + \dots + \frac{T_{en}}{G_1 G_2 \dots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(g/\Delta f_{rms} + f_{max})$

$$\text{where } \log_{10} g = \begin{cases} (-1 + 4 \log_{10} n)/20, & n \leq 240 \\ (-15 + 10 \log_{10} n)/20, & n > 240 \end{cases}$$

Relationship between C/N and S/N is given by:

$$\frac{C}{N} = \left(\frac{S}{N} \right) \left(\frac{b}{B} \right) \left(\frac{f_{max}}{\Delta f_{rms}} \right)^2 \frac{1}{pw}$$

End of Paper